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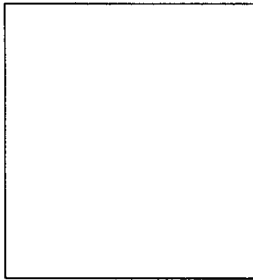
CHARM PRODUCTION AT RHIC

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The latest results for open charm and J/ψ production in p-p, d-Au and Au-Au from the PHENIX and STAR experiments at $\sqrt{s_{NN}} = 200$ GeV at RHIC are presented. The preliminary data show open charm production follows binary scaling in d-Au and Au-Au collisions at RHIC. In d-Au collisions, a suppression in J/ψ production has been observed at the forward rapidity (d direction), at the backward rapidity (Au direction), J/ψ production seems strongly dependent on collisions centrality. The implications of heavy flavor production in cold (d-Au) and hot (Au-Au) nuclear media at RHIC are discussed.

1 Introduction

Heavy flavor particles provide an important tool for studying the nuclear medium created in heavy ion collisions. The suppression of heavy quarkonium production in high energy heavy ion collisions is predicted as one of the signals for a phase transition of nuclear matter from confined to deconfined quarks and gluons, the so called quark-gluon plasma (QGP). However, other competing nuclear effects such as parton shadowing, heavy quark energy loss, and charm recombination will also affect the overall charmonium production. The hot nuclear medium created in heavy ion collisions could also increase charm production by opening up more phase space,[1] and therefore could affect both open charm and charmonium production.

A strong suppression of high p_T light hadron production has been observed at RHIC in Au-Au collisions,[2] which is most likely due to parton energy loss in the hot and dense nuclear medium (or QGP); for heavy quarks, this effect may be reduced due to the dead cone effect,[3] but this has not been confirmed by experimental data. The recent results for particle production at large forward and backward rapidity in d-Au collisions from the PHENIX experiment show that nuclear medium effects could play a significant role in the interpretation of the AuAu data at a large rapidity[4]. Therefore, it is very important to systematically measure open charm and J/ψ production in p-p, d-Au and Au-Au collisions to fully understand the underlying physics.
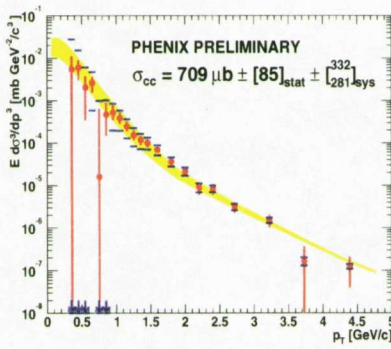
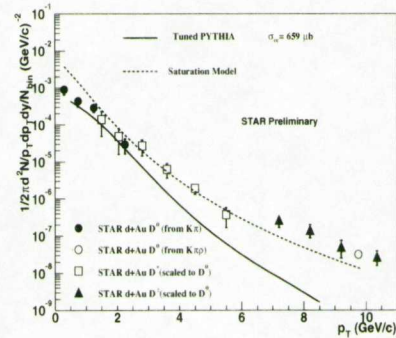Figure 1: Non-photonic electron p_T spectrum from p-p collisions.

Figure 2: D meson p_T spectrum in d-Au collisions.

2 Open charm production

At RHIC energies, open charm and J/ψ particles are predominantly produced through gluon-gluon fusion processes. Study of open charm production in p-p and d-Au collisions helps us to understand the normal nuclear effects, such as gluon (anti)shadowing and particle energy loss in cold nuclear medium. Open charm production in p-p and d-Au collisions also serves as a baseline for Au-Au system where hot and dense nuclear medium is expected to be created.

The PHENIX experiment has measured single electron spectra in p-p, d-Au and Au-Au collisions at central rapidity $|\eta| < 0.35$. [5] After subtracting the photonic contributions (photon conversion, Dalitz and other light hadron decays), the remaining electrons are mostly from open charm and open beauty semileptonic decays. Figure 1 shows the resulting single electron p_T spectrum in p-p collisions at $\sqrt{s} = 200$ GeV, from which the open charm total cross section is extracted, $\sigma_{c\bar{c}}^{pp} = 709 \pm 85(stat) \pm_{281}^{332} (sys)\mu b$.

The STAR experiment, on the other hand, has measured not only the inclusive electron spectra but also fully reconstructed the $D^{0,\pm}$ and D^* mesons at central rapidity $|\eta| < 0.5$ in hadronic channels, such as $D^0 \rightarrow \pi^- K^+$. This is the first direct measurement of open charm production at RHIC. [6] Figure 2 shows the reconstructed D meson p_T spectrum in d-Au collisions at $\sqrt{s_{NN}} = 200$ GeV. The scaled nucleon-nucleon open charm cross section is given by $\sigma_{c\bar{c}}^{NN} = 1.12 \pm 0.20(stat) \pm 0.37(sys)mb$, which is in a good agreement with the PHENIX results.

The effect of the nuclear medium on open charm production is studied by looking at (non-photonic) electron production as a function of collision centrality which is related to the impact parameter of two colliding nuclei. Figure 3 show the electron p_T spectra in 5 different centrality bins in Au-Au collisions, fitted to the electron p_T shape from p-p data. Figure 4 show the $< N_{coll} >$ scaled electron p_T spectra from minimum biased p-p, d-Au and Au-Au data from the PHENIX, where $< N_{coll} >$, the average number of binary collisions, is estimated through a Glauber model calculation. Figure 5 shows the $< N_{coll} >$ scaled single electron yield in Au-Au collision as a function of $< N_{coll} >$, the data points are integrated over $0.8 < p_T < 4.0$ GeV and $|\eta| < 0.35$ at each centrality bin. Within the experimental error, open charm production in d-Au and Au-Au system agrees with the binary scaling hypothesis. Thus it appears that there is no strong nuclear dependence of open charm production at RHIC.
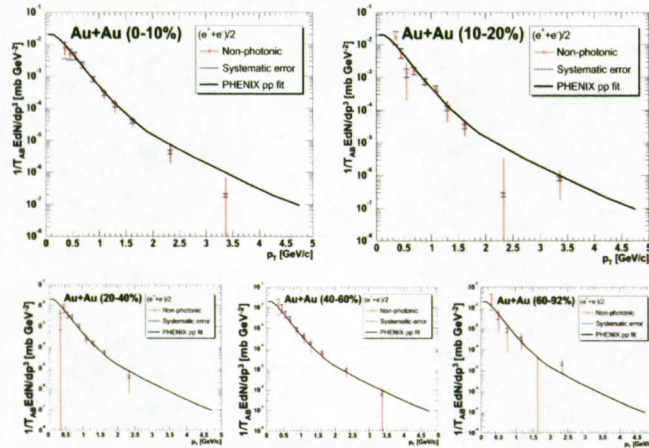
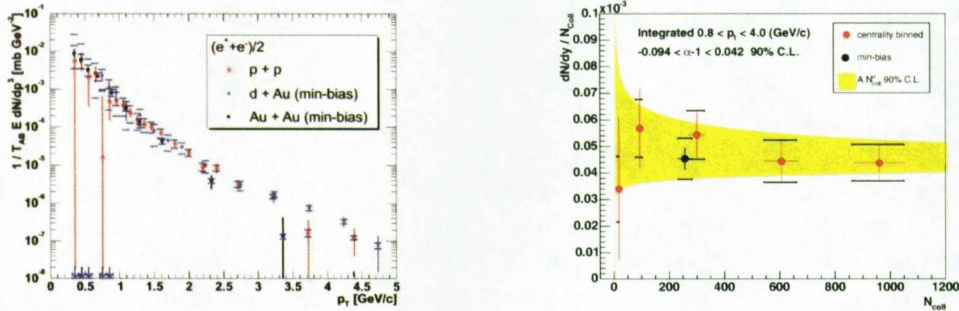Figure 3: Electron p_T spectra from 5 centrality classes in Au-Au collisions.

Figure 4: $< N_{coll} >$ scaled electron p_T spectra from p-p, d-Au and Au-Au collisions, from PHENIX.

Figure 5: Integrated electron $dN/dy/ < N_{coll} >$ vs $< N_{coll} >$ in Au-Au collisions, from PHENIX.

3 J/ψ production

J/ψ production is predicted to be sensitive to the creation of the QGP in heavy ion collisions and an anomalous suppression has been observed in Pb-Pb collisions at CERN [7]. It is very important to check J/ψ production in both the cold and hot nuclear media at RHIC.

The PHENIX experiment has measured J/ψ in both p-p and d-Au collisions through the dielectron and dimuon channels, with good statistics in the rapidity range $|\eta| < 0.35$ and $1.1 < |\eta| < 2.2$, [8] and expects to detect a few thousand of J/ψ particles from the high luminosity Au-Au run that just finished at RHIC this year.

The effects of cold nuclear medium on J/ψ production are studied in d-Au collisions by measuring the nuclear modification factor $R_{dA} = \frac{1}{2 \times 197} \frac{d\sigma^{dAu}/dy}{d\sigma^{pp}/dy}$, which is the ratio of the J/ψ yields observed in d-Au collisions relative to p-p system, scaled by 2×197. Figure 6 shows R_{dA} as a function of rapidity y. While this ratio is close to unity at $y = 0$, a suppression has been observed at the forward rapidity, indicating possible gluon shadowing in Au nuclei. Also plotted there are several theoretical model calculations [9] with different assumptions about gluon shadowing and energy loss. Due to limited statistics of the current data, it is difficult to quantify the contributions from various processes.
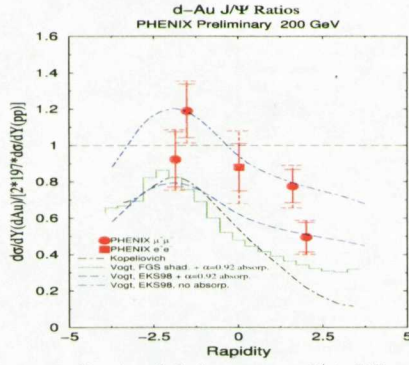
Figure 6: Ratio of d-Au to p-p J/ψ differential cross section versus rapidity, normalized by 2×197.
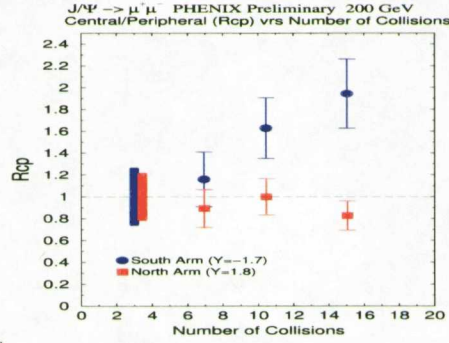
Figure 7: Centrality dependent J/ψ R_{CP} versus the average number of binary collisions in d-Au collisions.

The centrality dependence of J/ψ production in d-Au collisions has also been studied by PHENIX at both forward and backward rapidities. R_{CP}, the ratio of J/ψ yields normalized by $< N_{coll} >$ in each centrality bin relative to the most peripheral one, is shown in Figure 7. The preliminary data show a strong dependence of J/ψ production on collision centrality in the backward rapidity.

Conclusions

Open charm and J/ψ production have been measured by the PHENIX and STAR experiments in p-p, d-Au and Au-Au collisions at RHIC. A high statistic J/ψ measurement is expected from the recent high luminosity Au-Au run at RHIC. Within experimental errors, open charm production in d-Au and Au-Au collisions is consistent with a binary scaling hypothesis, indicating that there is no strong charm enhancement or suppression in heavy ion collisions at RHIC. From J/ψ measurements in p-p and d-Au systems, possible shadowing of gluon distribution functions have been observed at large forward rapidity in d-Au collisions, however, due to limited statistics of current data, we can't distinguish various theoretical models. An interesting observation is the strong centrality dependence of J/ψ production at the backward rapidity in d-Au collisions, as measured by PHENIX. Theoretical work to understand what have been observed in charm production at RHIC is in progress.

References

1. A.P. Kostyuk *et al.*, Phys. Lett. B531 195-202 (2002).
2. S.S. Adler *et al.*, Phys. Rev. Lett. 91, 072301 (2003).
3. Y.I. Dokshitzer and D.E. Kharzeev, Phys. Lett. B519, 199 (2001).
4. M.X. Liu, Quark Matter Conference,2004, nucl-exp/0403047.
5. H. Hamagaki *et al.*, Nucl. Phys. A698, 412 (2002); S. Kelly, Quark Matter Conference, 2004, nucl-ex/0405006.
6. T. An, Quark Matter Conference, 2004.
7. NA50 Collaboration, Phys.Lett. B477, 28 (2000).
8. R.G. de Cassagnac, Quark Matter Conference, 2004, nucl-ex/0403030.
9. S.R. Klein and R. Vogt, Phys. Rev. Lett. 91,142301 (2003); B. Kopeliovich, A. Tarasov and J. Hufner, Nucl. Phys. A696 669-714 (2001).